THE ANNUAL RAINFALL AND TEMPERATURE OF THE UNITED STATES.[1]

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A record of the annual temperature and rainfall of various stations scattered over a large territory, having wide variations of climate, can not give a very accurate idea of the mean annual temperature of the whole region, or of the total volume of precipitation upon its surface.

In "A report on Missouri rainfall"[2] for the years 1878–1887, inclusive, Prof. Nipher has shown the average number of cubic feet per second of water in the various forms of precipitation which fell upon the surface of the State during those years.

In the following work, which was also begun by Prof. Nipher and completed by the writer, an attempt has been made to compute the total precipitation on the main body of the United States, exclusive of Alaska and the outlying possessions; and also to find the average annual temperature of the same region as a whole. It would seem that this, or some similar method, is the proper way of expressing the climate of an entire country, such as the United States.

Twenty-eight manuscript maps, covering the 14 years 1891–1904, inclusive, were obtained from the office of the Weather Bureau at Washington. Half of these indicated the precipitation in inches per year, and the other 14 the mean annual temperature. The figures for these had been marked on the maps at the points of observation, and lines passing through points having equal precipitation and equal temperature had been drawn upon the maps by the weather officials. These lines divided the maps into zones or sections, one zone comprising, let us say, the territory whose mean annual temperature lay between 50° and 55°, the next 55° to 60°, etc.

It was intended at first to find the areas included in these several zones by the planimeter. Then, knowing the area over which the mean temperature was 50°, another over which it was 55°, etc., the average of the whole might easily be computed.

This integration by means of the planimeter was abandoned, however, for it was found by Prof. Nipher that the areas of different sections of the map as shown by the instrument were not proportional to the actual areas of those sections. It was also difficult to properly weight the values with respect to areas, unless the areas between the lines of equal value were subdivided into smaller areas.

The method actually adopted by Prof. Nipher was to take each State by itself, and for each year average all the observations recorded, also filling in values by interpolation methods where the reports were thinly scattered in some portions of the State as compared with other portions, so as to make the observations as evenly distributed as possible. These interpolated values were estimated by means of the values on each side of the deficient areas.

As an illustration, Minnesota has naturally a great many more stations reporting from the southern and southeastern parts of the State than from the northern; perhaps the lower half of the State would have three-fourths of the observations. It would be manifestly unfair to give the northern half of the State only one-third the weight of the southern half in determining the rainfall or average temperature. In some States no interpolation was necessary, in others a great many were added. Enough data were on the maps originally, however, to admit of these interpolations being made with a tolerable degree of accuracy.

In Missouri, in the year 1896, the number of observations of rainfall, including those interpolated, was 44. The average of these 44, or the average for the whole State, was 40.1 inches. If we multiply this 40.1 by the number of square miles in the State and divide by 63,360, which is the number of inches in a mile, we have the number of cubic miles of water which fell in the State during the year; that is, if τ is the precipitation in inches and A the area of the State $\frac{\tau A}{63360}$ is the number of cubic miles of water. This for Missouri in the year 1896, just mentioned, was 43.9 cubic miles. The total number of cubic miles of water falling in Missouri in the 14 years was 609.3, giving a mean of 43.5 cubic miles per year. This is at the rate of 203,000 cubic feet per second as compared with 195,800 cubic feet per second found by Prof. Nipher between 1877 and 1887. The maximum was in 1898, 60.9 cubic miles, 40 per cent above the average; the minimum was in 1901, 28.2 cubic miles, 35 per cent below the average. These two years, however, were very abnormal, the highest outside of 1898 being 49.1 cubic miles, and the lowest, excepting 1901, 34.6 cubic miles.

The 43.9 cubic miles which fell in Missouri in 1896 are alone enough to make a layer over the whole city of St. Louis (which has an area of 62½ square miles) 0.7 of a mile deep. If it could all be utilized it would make a river one-half mile wide, 16 feet deep, and 29,000 miles in length. If this flowed at the rate of 3 miles per hour, it would take over a year to pass a given point, so that enough water falls in Missouri to fill and keep flowing continuously a river of this cross section, and of the whole length of the Mississippi, and then enough would be left over each year to fill a canal of the same section from New York to San Francisco.

Prof. Nipher showed in his paper, before referred to, that the total rainfall in cubic miles falling upon the State of Missouri during the 10 years, was within 2 per cent equal to the discharge of the Mississippi River at St. Louis during that interval.

It may thus be seen that most of the water which falls as rain or snow never reaches the sea through the medium of drainage, but is evaporated from the land. If all the precipitation were led into the rivers and conducted back to the sea we should have mighty streams of water which would make our present ones seem as little brooks.

The discharge of the whole Mississippi system, however, is considerably greater than the river we have imagined. To make it more definite, the discharge of the Mississippi River at Carrollton, La., was computed for the 14 years. A discharge curve of the river at that station was constructed from simultaneous gauge readings and discharge observations taken from the reports of the Mississippi River Commission. From this a discharge curve for each year was constructed, and by mechanically integrating the areas under these curves, the discharge of the river at Carrollton was found for each year. These yearly discharges ranged from 76.3 cubic miles in 1895 to 154.7 cubic miles in 1903. The average was 117 cubic miles per year, or 545,800 cubic feet per second. This is less than three times the precipitation on the State of Missouri. It would be interesting to see what part this discharge is of the whole amount falling upon the area which drains into the Mississippi above its mouth.

After the precipitation for each State had been computed, the amounts were summed up in five districts:

[1] Read before The Academy of Science of St. Louis, June 5, 1911, and published in Trans. Acad. Sci. St. Louis, Vol. XXI, No. 2.
[2] Trans. Acad. Sci. St. Louis. 5:383.

the Northeast, the Southeast, the North Central, the South Central, and the Western. The Northeast division comprised the New England States, New York, New Jersey, and Pennsylvania. The Southeast division, Delaware, Maryland, West Virginia, and the South Atlantic States. The North Central, Ohio, Indiana, Illinois, Wisconsin, Michigan, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas. The South Central, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Texas, and Oklahoma. The Western division comprised the remaining States to the West.

In the year 1896 the total rainfall on the Northeast section was 98.9 cubic miles; on the Southeast, 199.7; on the North Central, 363; on the South Central, 308.8, and on the Western, 326, making a total for the United States of 1,296.4 cubic miles. This is about 30 times as much as falls in Missouri in one year. The greatest annual volume of precipitation during the years considered was in 1902, when 1,396.9 cubic miles fell. In 1894, the year of minimum fall, there was only 1,199.1, a difference of about 200 cubic miles.

The average yearly temperature for the whole country was obtained as follows: the average for each State was found, just as in the case of the rainfall, by averaging the values of the several station reports, together with interpolated values, multiplying the average by the area of the State, adding these products for all the States, and dividing the sum by the area of the whole United States.

This gives for the average temperature of the United States for successive years the values shown in the table below.

It will be seen that the values are remarkably constant, the highest in the 14 years being 54.4° in 1900 and the lowest 51.4° in 1894, a difference of only 3°. The mean for the period being 52.9°, the greatest variation was only 1.5° above or below this.

We may say then that, taking the 14 years as a basis, the average annual temperature of the United States, excluding the outlying parts, is 52.9° F., and the annual precipitation is 1,308 cubic miles.

The State having the lowest amount of precipitation in any year was Arizona in 1894, 5.8 inches; the greatest, Alabama in 1900, 71.6 inches. The State having the lowest average temperature was North Dakota in 1893, 35.5°; the highest, Florida in 1897, 71.8°. These, of course, are far from representing the extremes for small areas. The maximum rainfall for single stations is not in Alabama at all, but on the North Pacific coast, where in Washington and Oregon the rainfall is very often more than 100 inches per year, while some areas are, of course, practically rainless.

Many attempts have been made to show a periodic variation of the temperature and rainfall, and to connect this period with some celestial phenomenon, as sun spots. While there seems to be a tendency, especially in the first part of the 14 years, for a minimum of temperature and rainfall to occur at a maximum of sun spots, the latter part of the period covered is erratic in both the temperature and precipitation curves. The fluctuation is a large fraction of the general periodic change which coincides fairly well with the sun-spot period. A continuation of this work through the next sun-spot period may yield more conclusive results.

Brückner has constructed a table of world temperatures and precipitation from about 1731 to 1885, which he finds, apparently, indicates a period for both of about 35 years. The interval, however, between maxima and minima varies from 4 to 30 years. The maxima for temperature and rainfall sometimes fall together and sometimes a maximum of temperature coincides with a minimum of rainfall.

It may be considered then that the most that may be said is that there are not yet enough data, or perhaps, better, not enough work has been done on the vast amount of data already accumulated, to show with any certainty, or even probability, that any celestial phenomena govern the variation of temperature and precipitation from year to year. The remarkable thing is that the yearly variation is so small, considering the great storms and great variations of temperature extending over short periods. This very uniformity is perhaps more wonderful than the discovery of some celestial cause for the variation.

The integrated values for the entire country evidently furnish a much more reliable basis for a study of climatic conditions upon the earth than could ever be obtained by observations at isolated stations.

Average temperature and precipitation of the United States.

Year.	Average temperature.	Precipitation.	Year.	Average temperature.	Precipitation.
	F.	*Cubic miles.*		*F.*	*Cubic miles.*
1891	52.6	1,352.0	1898	52.9	1,366.2
1892	52.5	1,362.1	1899	52.8	1,298.2
1893	51.9	1,277.5	1900	54.4	1,352.9
1894	51.4	1,199.1	1901	53.5	1,254.3
1895	53.2	1,249.8	1902	53.3	1,396.9
1896	54.1	1,296.4	1903	52.1	1,345.4
1897	53.0	1,340.3	1904	52.4	1,235.0